June 27, 1983

AN ECOLOGICAL SURVEY OF THE FRENZEL CREEK RESEARCH NATURAL AREA, MENDOCINO NATIONAL FOREST, COLUSA COUNTY, CALIFORNIA

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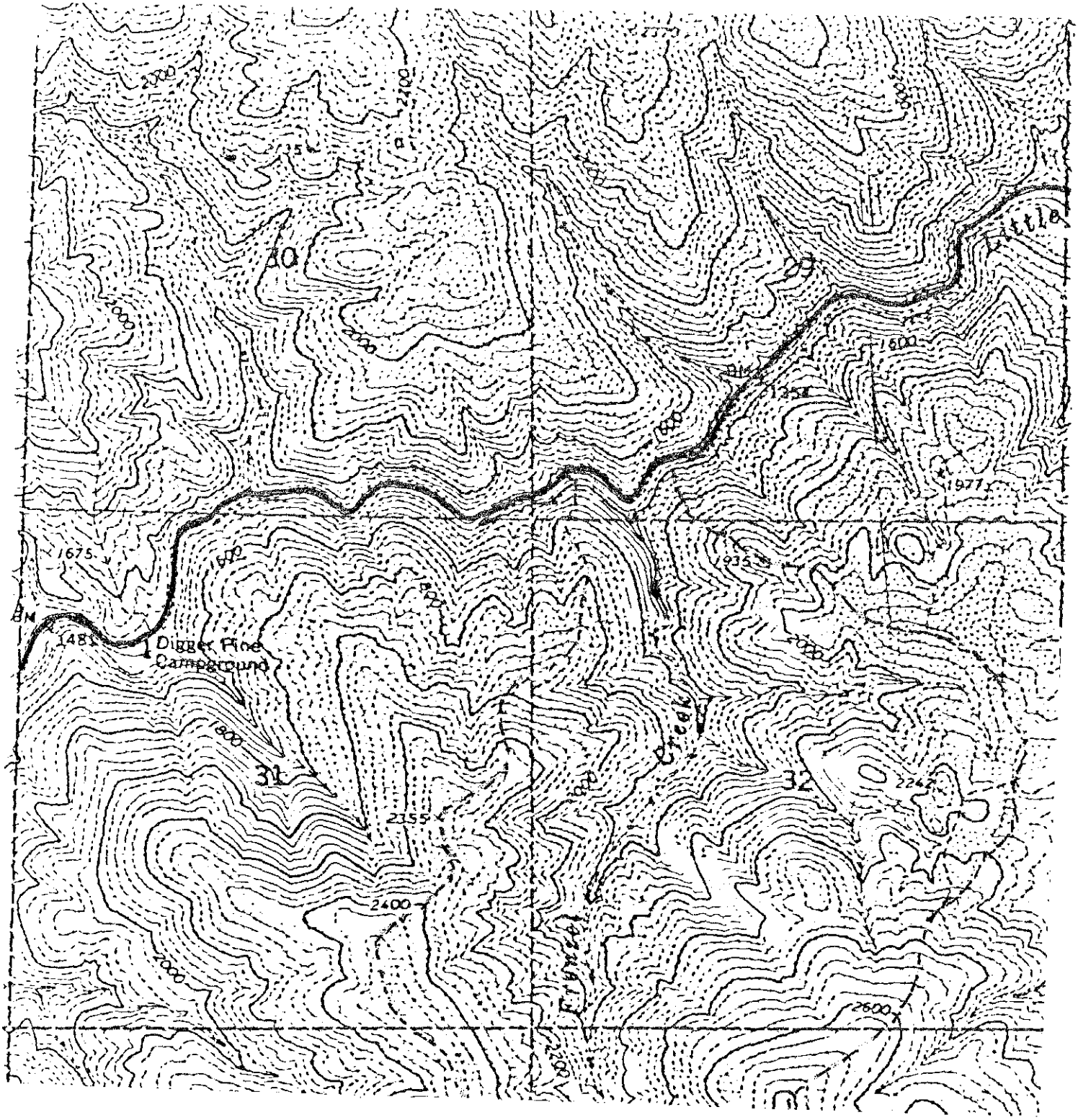
I. LOCATION AND HISTORY OF ESTABLISHMENT

The Frenzel Creek RNA is located on the Mendocino National Forest, Stonyford Ranger District. The northern end of the RNA, at the junction of Little Stony Creek and Frenzel Creek lies about six air miles SSW of the town of Stonyford, Colusa County. The northern section of the area may be reached by traveling up Goat Mountain Road for ca. 2.5 miles from the Stonyford-Lodoga Road. From there Little Stony Creek must be forded (somewhat difficult in spring). The upper reaches of the area may be reached by a rough four-wheel drive road (17N31 to 6W10) which descends Lovelady Ridge from Pacific Ridge. The entire drainage, ca. 830 acres, is included within the Frenzel Creek RNA boundaries. Elevations range from ca. 1390 ft. at Little Stony Cr. to 3090 ft. at the head of the drainage (for further detail see map 1).

The suggestion that Frenzel Cr. would make a suitable serpentinite research area was first made in 1966 by Jim Griffin, then plant ecologist with the Forest Service at Redding . Additional letters of support came from G.L. Stebbins, Professor of Genetics at U.C. Davis, in 1970. These letters stressed the ecological and evolutionary significance of the two sympatric species of cypress and several species of rare and unusual herbs known from the drainage. In January 1971 the official establishment report on Frenzel Creek was issued. Apart from a rough vegetation type map drawn in 1970 and a preliminary list of vascular plants including ca. 100 taxa (Isle et al. 1978) no further biotic studies of the area have been made.


30
29
31
32
1675
1481
Digger Pine
Campground
2355
2400
1977
1600
2600
2000
2200
2800
2400
1800
1600
1400
1200
1000
800
600
400
200

II. IMPORTANT FEATURES OF THE SERPENTINITE FLORA OF FRENZEL CREEK

A. Distribution and Regeneration of MacNab Cypress

Cupressus macnabiana is the most widespread of the 10 California cypresses. It is known from over 30 populations in 12 Northern California counties (Vogl et al, 1977). MacNab populations are most densely aggregated in Lake County and its bordering counties, but occur through the North Coast Ranges and Eastern Klamath Province from Napa to Shasta Counties and in the Northern Sierra-Southern Cascade foothills from Amador to Shasta Counties. The Sierra-Cascade populations may occur on greenstone, basalt, gabbro, conglomerate, and serpentinite. However, the North Coast Range populations are much more restricted to serpentinite (Griffin and Critchfield 1972). The Frenzel Creek population is at the northern end of the largest nearly continuous stand known for the species, stretching for over 15 miles along the border of Lake and Colusa counties.

Because of the more diverse substrate types found in the Sierra-Cascade populations it appears that there may be some historical differences between the Coast Range and Sierra plants. Are the Coast Range plants more intolerant of non-serpentinite soils? Does this presumed difference reflect past inequalities in the competitive relationships between MacNab and other Coast Range and Sierra plants when the climate of the Plio-Pleistocene was drying? These and other questions might be answered by comparative research on the Sierra and Coast Range Populations.

C. macnabiana along with C. bakeri, C. nevadensis, and C. stephensonii is characterized by being strongly aromatic and having small resin pits on the dorsal surface of the scales (Wolf 1948). Concurrent with these taxonomic similarities, these four species share a more inland

distribution than the six other California Cupressus. This suggests that the resin pits and, presumably, accompanying terpenoid differences confer an advantage in drier habitats away from the more mesic (summer fog) maritime climate generally experienced by the other species.

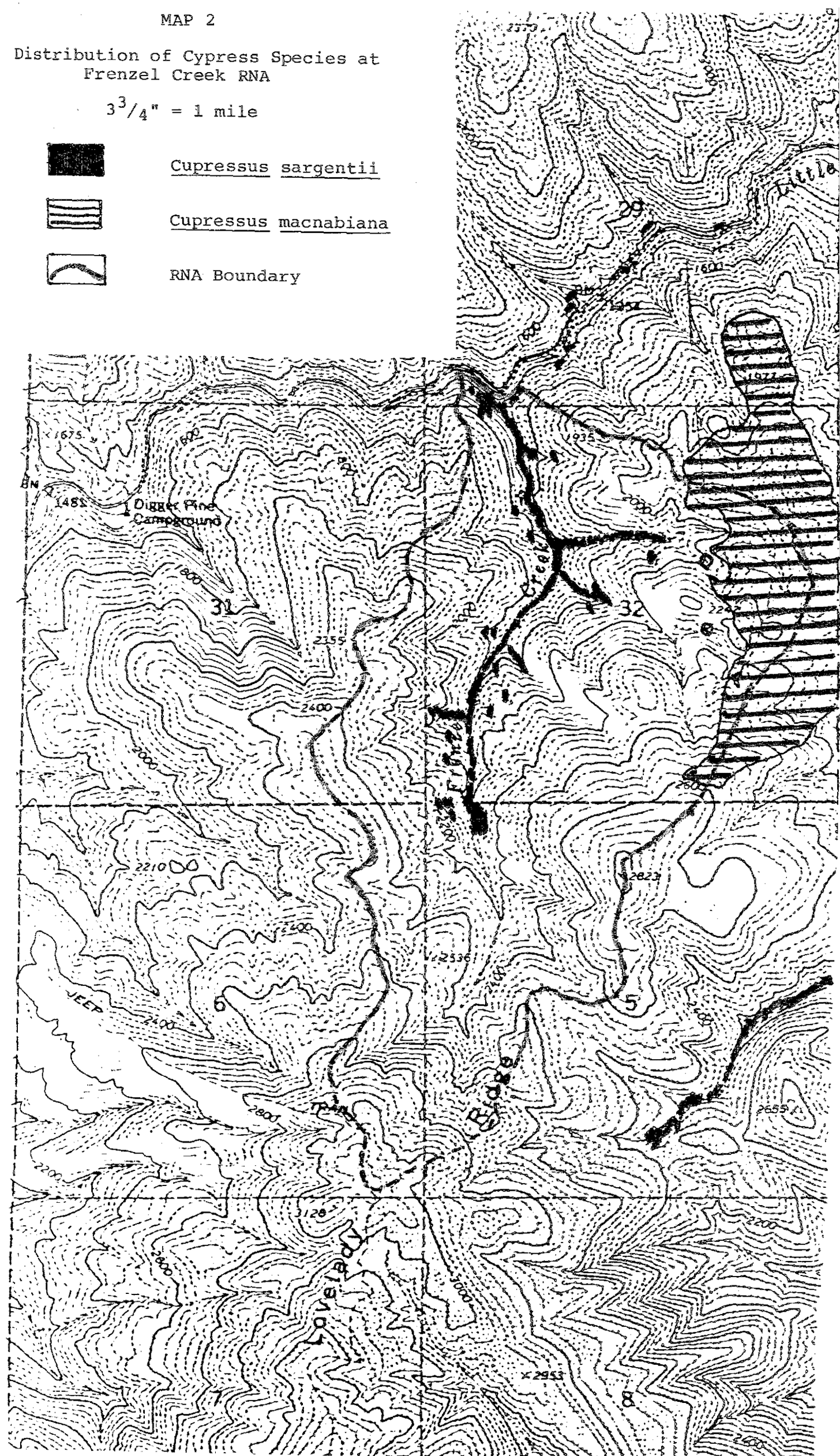
The population of C. macnabiana on Lovelady Ridge (see map 2) is fairly typical of its Inner Coast Range distribution (Griffin and Stone 1967). It shares many characteristics with the population on Raglin Ridge in Tehama County (Keeler-Wolf and Keeler-Wolf 1974). In large areas the trees are generally 8-12 feet tall and densely aggregated, however, some of the population is more widely scattered among a lesser mixture of Arctostaphylos viscida, Quercus durata, and other shrubs. These more widely dispersed and taller stands (10-15 ft.) designate areas of old growth chaparral which apparently have not burned for at least 50 to 60 years. Dense stands of small stature MacNab (3 - 6 ft.) occur locally in more recently burned areas (e.g., the 1950 Frenzel Burn). In all cases MacNab occupies the upper slopes and ridges, only rarely dropping into the upper reaches of ravines and canyons.

MacNab Cypress is almost always ecologically and invariably geographically distinct from the sympatric Sargent Cypress at Frenzel Creek. MacNab's restriction to ridgetops may in some way be a result of competitive exclusion by Sargent Cypress and other species from the seemingly more favorable valley bottom sites. But a more parsimonious explanation may lie in MacNab's apparent strict dependence on fire for regeneration (see vegetation section). Because of their greater exposure to lightning strikes and the tendancy for fires to burn uphill, ridges are more prone to frequent burning than valley bottoms. All California cypresses are considered to be fire-adapted (Vogl et al, 1977). However, the relative difference between the typical regenerative mode of MacNab and Sargent Cypress at Frenzel Creek may be significant.

MAP 2

Distribution of Cypress Species at Frenzel Creek RNA

$3\frac{3}{4}$" = 1 mile



B. Distribution and Regeneration of Sargent Cypress

Among the California cypresses , C. sargentii is second only to C. macnabiana in the extent of its distribution (Vogl et al. 1977). However, unlike MacNab, Sargent is a species restricted to the coastal mountains of Central and Northern California. Its most interior population appears to be at Cooks Springs, Colusa County, only about 1.5 miles southeast of Frenzel Creek. (Peattie 1953). Sargent is strongly restricted to serpentinite throughout its range and usually occurs along creeks and on mesic slopes (Griffin and Critchfield 1972). Its westernmost stands may border redwood forest (eg., Sonoma Co.). C. sargentii may be considered a more inland species than its closest relatives C. abramsiana, and C. goveniana. Never-the-less, its affinities for creeksides, particularly in the Inner Coast Ranges, indicate that it is adapted to a more mesic environment than C. macnabiana.

The ancestor of C. sargentii may have been a more widespread coastal species in Miocene and Pliocene (Raven and Axelrod 1978) which became more restricted to serpentinite (or sterile, sandy soil as with Abrams and Gowen Cypress) as the interspecific competition in coastal habitats grew keener, presumably in late Pliocene and early Pleistocene. One likely reason why many of the California cypresses are restricted to poor soils is that they are shade intolerant (Vogl et al. 1977). Perhaps Sargent is the most interior of the typical coastal Cupressus because it can effectively exploit a mesic (riparian) habitat which does not contain as many relatively shade-tolerant tree competitors as other coastal localities; namely, the serpentinite riparian zone.

As with MacNab Cypress, Sargent's densest population aggregations are in and around Lake County, but as with the Frenzel populations the two species are not usually syntopic. Evidence of hybridization of these, the only two sympatric California Cypresses, is rare (Griffin and

Critchfield 1972). This is most likely a result of the rather long period of genetic isolation of the two species and their relatives. MacNab, at least, has been specifically distinct since the Miocene (Raven and Axelrod 1978).

The young seedlings and saplings of C. sargentii are very elongated commonly with a length between 100 and 150 times their basal diameter. This is likely to be a result of the more intense competition for light in the shady and densely vegetated riparian and canyon bottom habitats. Possibly the species can tolerate more shade than MacNab, and this may offer an additional explanation for the ecological separation of the two species.

Regeneration of Sargent Cypress regularly occurs without the aid of fire. This is evidenced by the multi-aged stands (see vegetation section) along Frenzel Creek where no fire scarred snags and stumps occur. In vegetation plots off of recent burns there are still usually some small seedlings 1-5 years old. And in 20+year-old burn areas new seedlings (presumably from the young 20-year-old trees) are springing up regularly. In contrast, the MacNab stands observed contained no young seedlings or saplings under 20 years old off of the burns, and only a handfull of young seedlings (under 10 years) on the most recent ridgetop burn (1950).

Both cypresses may open their cones enough to release at least some seeds after a few years on the branch (cones are commonly split to ca. 3 mm on both). Thus, it seems likely that the differential regeneration is a result of a more consistantly favorable germination environment for Sargent along the mesic valley bottoms &/or the rarity of a necessary disturbance (such as a fire with the added macronutrients from burned vegetation, or the bulldozing of a fire break on the ridges) for MacNab.

C. Numbers and Types of Serpentinite Endemics

There are about 36 taxa in the RNA which are generally considered to be restricted to serpentinite soils. (Raven and Axelrod 1978, Munz 1968, Gottlieb 1968). Raven and Axelrod have distinguished between three types of serpentinite-tolerant species. Although these types were based primarily on their degree of serpentinite restriction, they also show a trend for the woody species of more ancient origins (paleo-endemics) to occur more widely off serpentinite than the more wholly restricted, rapidly evolving herbaceous species (neo-endemics).

At Frenzel Creek there are far fewer paleo-endemics than neo-endemics, though the few are among the most important members of the vegetation. They include Sargent and MacNab Cypress, Garrya congdoni, Quercus durata, Ceanothus jepsonii var. albiflorus, Salix breweri, and possibly Arctostaphylos viscida. Because many of these species have disjunct ranges throughout the state, and because serpentinite in the Napa-Lake-Colusa County area as well as over much of California was largely covered by volcanics and other rocks until late Pliocene or Pleistocene (Raven and Axelrod 1978), it is likely that all of these species occurred more widely off serpentinite in the past.

Conversely, many of the herbs comprising the interesting serpentine flora of Frenzel Creek are thought by Raven and Axelrod to be recently derived species which evolved from non-serpentinite species in ways similar to the scenario described by Kruckeberg (1954). Many of these species are limited in their distribution and most appear to have evolved in situ. The following 29 species are likely to be in this neo-endemic category:

Allium sp.?
Allium falcifolium
Antirrhinum subcordatum
Aquilegia eximia
Asclepias solanoana
Chlorogalum pomeridianum var minus
Castilleja miniata ssp. nov.

Tritelia peduncularis	Astragalus clevelandii
Carex serratodens	Nemacladus montanus
Clarkia gracilis ssp. albicaulis	Rhamnus californica ssp. crassifolia
Claytonia spathulata var. exigua	Senecio clevelandii
Claytonia gypsophylloides	Senecio greenei
Calystegia subacaulis	Silene campanulata ssp glandulosa
Galium andrewsii	Strept anthus breweri
Hesperolinon californicum	Streptanthus breweri var. hesperidus
Hesperolinon drymarioides	Strept anthus morrisonii
Eriogonum ursinum var. nervulosum	Stachys pycnantha
Mimulus brachiatus	Zigadenus fontanus

Because of the extensive areas of serpentinite exposed in the North Coast Ranges, particularly in Napa, Lake, Sonoma, and Colusa counties, the serpentinite flora in this area is among the richest in California. Such exemplary serpentinite genera as Streptanthus and Hesperolinon have more species occurring here than in any similar sized area in the state. It is likely that there are several species in the area which are currently evolving distinct serpentinite forms.

D. Rare and Endangered Plants

Eight taxa of the Frenzel Creek drainage are listed by Powell (1974) as being rare or very rare and endangered in California. They include:

Astragalus clevelandii	Mimulus glaucescens
Antirrhinum subcordatum	Nemacladus montanus
Hesperolinon drymarioides	Senecio clevelandii
Mimulus brachiatus	Streptanthus morrisonii

S. clevelandii is listed as rare and not endangered. It is a Lake and Colusa County endemic and in the RNA is confined to a few mossy seeps near the confluence of Frenzel and Little Stony Creeks. H. drymarioides is considered very rare and endangered. It is known only from

a few populations in Lake and Colusa counties and was collected by Isle et al. (1978) in the RNA. S. morrisonii (aff.) is a very rare and endangered species known only from Sonoma, Lake, and if this is indeed the species, Colusa counties. There are two subspecies in addition to the species, and it is unclear if the Frenzel populations belong more properly to one of these taxa or if they are an undescribed subspecies. The general habit and the greenish-yellow calyx do fit the species description more closely than S. brachiatus, another Lake County plant. This Streptanthus is the most characteristic species of the serpentinite barrens and appears to occur on all of the major barrens in the RNA.

Mimulus brachiatus is an annual pink-flowered monkey flower (fig. 1) species endemic to the serpentinite moist gravelly banks of Lake and Colusa Counties. It is locally common in several places in the RNA. Mimulus glaucescens is a close relative of the widespread and common M. guttatus, endemic to the valley and foothill areas of the Sacramento Valley. It is considered rare and not endangered, yet only two plants were seen in the RNA along the upper reaches of a tributary of Frenzel Cr. Nemacladus montanus is another rare and not endangered plant endemic to the North Coast Ranges from Napa to Colusa counties. I saw only one population in the RNA in a sunny rocky opening about halfway up the east side of Frenzel Creek. Antirrhinum subcordatum is very rare and endangered, known only from a few populations on serpentinite in Colusa and Glenn counties. This plant was collected by Isle et al. in 1978.

Astragalus clevelandii is a rare and not endangered serpentinite plant which is known from scattered stations in the North and South Coast Ranges. Only one individual was seen in the RNA, along Little Stony Creek. It is unique in that there appears to be a nearly 300km gap in its distribution between Napa and San Benito counties. Because of the range and the distinctness of this species it may be of more ancient origin than most other herbaceous serpentinite endemics (Raven and Axelrod 1978).

E. New and Undetermined Taxa

During the field work for this report two taxa of plants were collected from the RNA which did not fit any descriptions in published floras of California.

The first plant is an Allium which occurs in at least two populations on serpentinite barrens on the east side of the drainage. This wild onion flowers in late April, its pale pink flowers contrasting strongly with the rich purple of the common chaparral species A. falcifolium (fig.2). Its combination of three floral bracts, a greenish mid-vein, two rather falcate leaves, and unreticulated bulb coat plus its restriction to harsh serpentinite barrens is unique. Closest species appear to be A. tribracteatum, A. yosemitensis, and A. parvum of higher elevations in the Sierra-Cascade and Modoc Plateau regions. The specimens I collected are currently being studied by a specialist at The University of the Pacific.

The other plant is a Castilleja that is one of the indicator plants of the strict riparian zone along Frenzel Creek. L. R. Heckard of U.C. Berkeley believes it is an undescribed subspecies of the widespread and highly variable C. miniata complex. In general habit it resembles typical C. miniata from the montane areas of California. However, it is very distinct in its deeply divided lanceolate calyx lobes, its entire floral bracts, and its thickened, entire, narrowly lanceolate leaves (fig.3). Other distinctive populations in the miniata group have been afforded specific status in the past, such as C. uliginosa (the Pitkin Marsh Paintbrush). However, now the group is recognized as a large polyploid complex with many subspecies or varieties. Much more study is needed before the relationships of the Frenzel Creek plant to others in the group is understood. This taxon also occurs at Cooks Springs, ca. two miles to the east of Frenzel, and should be looked for along other serpentinite streams in the Lake-Colusa Co. area.

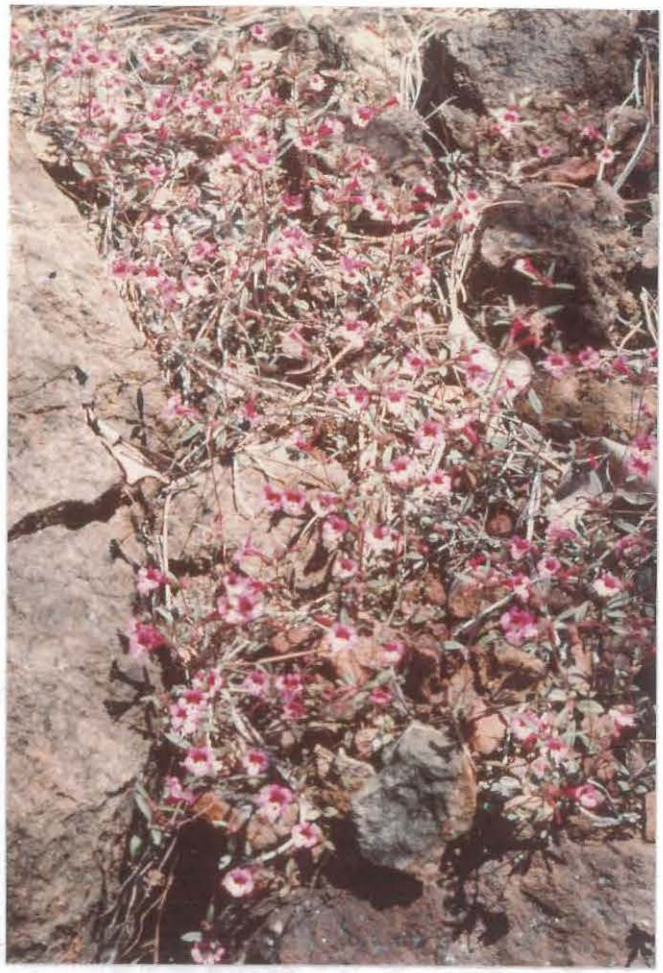


Figure 1. A population of Mimulus brachiatus along an intermittent tributary of Frenzel Cr.

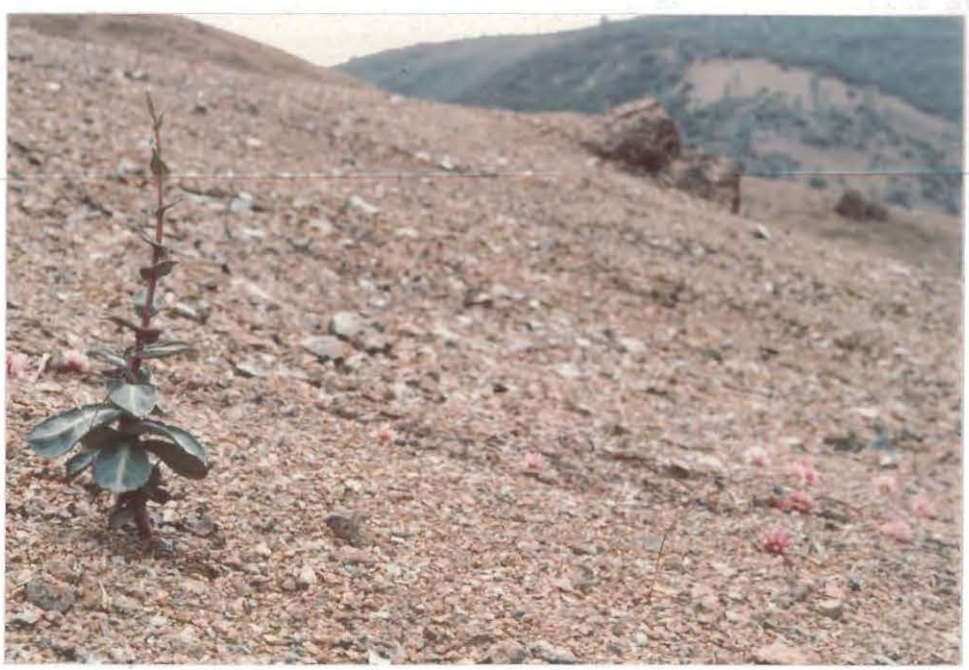


Figure 2. A young Streptanthus morrisonii flanked by several individuals of Allium cratericola var. nov., serpentinite barrens eastern Frenzel Cr. drainage, April 1983.

Figure 3. Castilleja miniata ssp. nov. along seep above Little Stony Cr., June 1983.

III. GEOLOGY AND SOILS

The major distinguishing geologic feature of the RNA is of course, the large exposures of serpentinized peridotite, which cover over 75% of the area. The serpentinite at Frenzel Creek is part of the largest ultramafic (primarily serpentinite) body in the California Coast Range (Bailey et al. 1964). It is a nearly continuous band 0.5 to 5 miles wide running along the east side of the Inner North Coast Range for more than 70 miles.

This serpentinite band is associated with the Stony Creek Fault, a nearly vertical thrust fault separating the contorted Franciscan Formation to the west from the more continuous, undistorted beds of the Great Valley Sequence to the east. The Stony Creek Fault is old, at least early Tertiary, if not late Jurassic or early Cretaceous (Page 1966) and has not been active since that time.

The position of the serpentinite around this thrust fault, its origins, and the serpentinite's relationship to the Franciscan and Great Valley rocks were among the great mysteries of California geology (Bailey et al. 1964, Brown 1964, Page 1966) until the theories of plate tectonics were applied to this area. The late Jurassic or early Cretaceous age of both the Great Valley and Franciscan formations made the Stony Creek Fault difficult to interpret in terms of a typical thrust fault. Normally in such cases younger rocks overly much older rocks.

The present interpretation (e.g., Alt and Hyndman 1975) contends that both the Franciscan and Great Valley rocks were ocean floor sediments deposited simultaneously off the shore of North America. The Franciscan was deposited farther off shore, evidenced by the abundance of chert (a deep ocean organic sediment), than the sands, shales and conglomerates of the Great Valley Sequence. Great Valley rocks were

thought to have been deposited on the old continental shelf and margin. The extremely chaotic nature of the Franciscan is a result of a continual scraping and jamming of its ocean floor sediments under the rocks of the Great Valley Sequence and the old continental edge during a long period of collision between the Pacific and North American Plates. With continual collision for perhaps 50 m.y. the sediment layers jammed under the continental margin created the thick welt known now as the coast ranges.

The serpentinite that occurs in the North Coast Ranges is thought to be sea-floor igneous rock (mostly peridotite) which was altered by the long-term permiation by sea water (from the wet overlying sediments). This altered peridotite may have once intruded the thin basalt sea floo and was then covered by the sediments of the Great Valley Sequence.

Serpentinite is a very mobile rock. For example, roads and mines in serpentinite areas are frequently plagued by slides, slumping, cave-ins, etc. The plastic properties of the rock make it behave, under pressure, almost like molten magma. Apparently when the Franciscan sediments were being jammed under the bed of serpentinite which underlay the 40,000+ feet of Great Valley rocks, the serpentinite was squeezed up unevenly like grease through any existing weak spots in the surrounding rocks. This fluid property resulted in the many sills, dikes, and lenses of serpentinite associated with the Franciscan terrane and the varying thickness of the main serpentinite exposures along the Stony Creek Fault Zone. It also resulted in the younger age of emplacement of the serpentinite than the apparent age of folding of many of the Franciscan rocks in the area (Brown et al. 1981). The serpentinite was thu apparently squeezed slowly up along faults and fissures created by the prior deformation of the Franciscan rocks.

Serpentinite contains higher concentrations of magnetic minerals

than the surrounding North Coast Range rocks. Recent interpretation of aeromagnetic surveys of the Snow Mountain-Stonyford area (Brown et al. 1981) confirm the presence of large serpentinite bodies stretching to below sea level under the mountains along the Stony Creek Fault Zone. The dipping angle of these beds is about 70°. It is likely that the serpentinite continues to plunge under the earth's crust at this angle until it meets the mantle, upon which the entire mass must have rested before being uplifted by the Franciscan Formation.

The serpentinite at Frenzel Creek can be subdivided into two basic types; blocks and matrix (see Bailey et al. 1964). The blocks are typically relatively solid, unsheared outcrops of red-brown to shiny gray-green rocks. Outcrops may be up to 50 ft. high but are often only a few feet across. A closer inspection of these blocks usually shows large (to 1cm) phenocrysts of dark minerals (pyroxine altered to bastite) set in a groundmass of serpentinized olivene. The matrix is distinguished by highly sheared, often crumbly rock ranging from three to ten inch fragments to sandy, or even clay texture. The color is usually dull to bright rusty brown. The most well-developed matrix areas are so inhospitable to most plant growth that they are commonly known as serpentine barrens and can be easily mapped from aerial photographs (see vegetation map). In general, matrix covers more area than blocks at Frenzel Creek.

The most influential feature of the serpentinite on the vegetation of Frenzel Creek is its anomalous chemical composition. Unlike most continental rocks serpentinite has an extremely high concentration of MgO (between 30&40% in samples cited in Bailey et al. 1964). This is about ten times as high as samples of Franciscan and Great Valley sediments and metasediments. Conversely, the macronutrient Ca (in the form of CaO) is almost completely absent from serpentinite, while it may comprise 2-16% of other surrounding rocks (Bailey et al. 1964).

According to Salisbury and Ross (1969) calcium as used by most plants is actually required in very small concentrations. However, if normal plant growth is to be obtained, larger quantities are necessary to reduce levels of certain other cations in soil, particularly magnesium, copper, and iron. Because Mg is in such high concentrations in serpentinite it is absorbed by most plants in excessive concentrations and the lack of sufficient Ca prevents detoxification.

In addition to Mg, serpentinite also often has excessively high toxic concentrations of Ni, Co, and Cr. Other essential macronutrients such as N, K, and P are often deficient because of the low organic content of the soil, and the micronutrient Mo is also usually in very low concentrations. Various authors (e.g., Kruckeberg 1954, Whittaker 1954) have investigated the endemism and specialized nature of many of the plant species found on serpentinite. Even for many of the serpentinite-tolerent plants certain highly sheared matrix zones (barrens) create such a harsh physical substrate that only a few highly adapted herbs can grow there.

Non-serpentinized Rock:

There is a small area of Franciscan-related rock in the upper drainage of Frenzel Creek. This has gone without mention in previous reports on the RNA, though it is clearly mapped by Brown (1964). Brown considers this zone to be composed of Lower Cretaceous cataclastic "friction-carpet" rocks. This zone in the drainage is made up of tan colored graywacke, muddy brown and gray shales, and darker gray metamorphosed sediments such as glaucophane schist. Large sections of these rocks are extremely crumbly and sheared indicating that this zone abutted the thrust fault during its movement (hence, the name "friction-carpet"). Thicker, unaltered beds of light gray schistose rocks marbled with quartz veins occur locally along the bed of upper Frenzel Creek.

These rocks are closely related to the Knoxville series of the Great Valley Sequence, which outcrops just northeast of the RNA. However, because they are west of the main serpentinite belt and the fault zone, they may be considered part of the Franciscan assemblage. The depositional environment for the adjacent Great Valley and Franciscan sediments was clearly almost identical. A small flow of pillow basalt and flow breccia, typical of the Franciscan formation occurs on the ridge in the southwest portion of the RNA.

The friction carpet rocks carry a distinct group of vegetation types (see figure 4) easily distinguished on aerial photographs by their high density and dark color in contrast to serpentinite vegetation Soils:

The serpentinite zone is covered by Heneke soils. Often these "soils" are technically non-existant in the sense that sheared bedrock is at the surface and there is no appreciable organic matter in the sparsely vegetated zones. Only in the riparian zone and directly under the larger shrubs of the serpentinite chaparral is vegetation regularly thick enough to create a thin layer of duff and humus.

One surprising fact of serpentinite soils is that they are typically moister than other soils in similar environments and microclimates (Raven and Axelrod 1978). This may have to do with their inability to bind as much H_2O as the surrounding cataclastic rocks. On the average, serpentinite samples from the North Coast Ranges contain ca. 12% H_2O, a much higher concentration than from any other sampled rock in the area (Bailey et al. 1964). Hence, less water can be absorbed into the rock and held chemically and more may become physically available in the interstices and is released in springs and seeps. Indications of the moistness of the Frenzel Creek serpentinite include: the abundance of many low-volume, yet permanent or semi-permanent streams; the presence of such typical

mesophytic species as Umbellularia and Salix breweri far above any permanent stream; and the deposition of silica on surface rocks reflecting ample capillary water rising to the surface. Thus, for the plants adapted to the harsh chemical composition of the soil, the moist serpentinite may actually be a favorable substrate in that it helps to compensate for the long summer drought.

The sedimentary-derived soils at the upper end of the drainage are generally better developed than the serpentinite soil. As a rule they have more organic matter in the 'A' horizon resulting from the denser vegetation. Ridgetop and steeply sloping soils are still thin and rocky, although there are far fewer blocks and outcrops of resistant rocks. The typical steep surface is covered with small angular fragments of shale less than an inch across. More gentle slopes on schist develop clay-rich layers on which small grassy areas develop. These patches of argillaceous soil are similar to the Hull Series further north in the Tehama County coast range (Gowen 1967).

Depending upon slope exposure the rocky soils derived from the sedimentary friction-carpet series may either be covered by chaparral or pine-oak woodland (see vegetation section). Most of these soils are probably in the Josephine and Sheetiron series (Gowen 1967).

IV. CLIMATE

Yearly precipitation in the Frenzel drainage probably averages between ca. 32 and 38 inches. July and August are the most severe drought months only averaging trace amounts of rain. The wettest months are December through March and each probably averages between five and seven inches. Snow is likely only to fall on a few days each winter at the upper elevations and probably does not remain on the ground for more than 24 hours. Thunder storms are occasional and may occur at any time of the year, though the most ecologically important ones (for initiating fires) must occur in the summer and early fall. Estimates on precipitation are from Kahrl (1979).

Temperatures are relatively mild in the winter with the average minima probably in the mid 20's (F). Summer maxima are relatively high, probably in the range of 102-106^{o}F.

V. VEGETATION

Serpentinite Riparian and Valley Bottom:

This is the most hydrophyllic type of vegetation on serpentinite in the RNA. It typically consists of dense stands of various shrubs and trees along the banks and lower canyons of Frenzel Creek and several of its permanent tributaries. The serpentinite riparian at Frenzel Cr. can really be subdivided into three sub-types: 1) a strict riparian zone where all plants have their roots bathed in year-around moisture; 2) a mesophytic valley bottom association which is tied to moist, shady valley bottoms or north slopes, but not necessarily to year-around water; and 3) an herbaceous rivulet association occurring along intermittant sunny streams, usually at the head of small creeks.

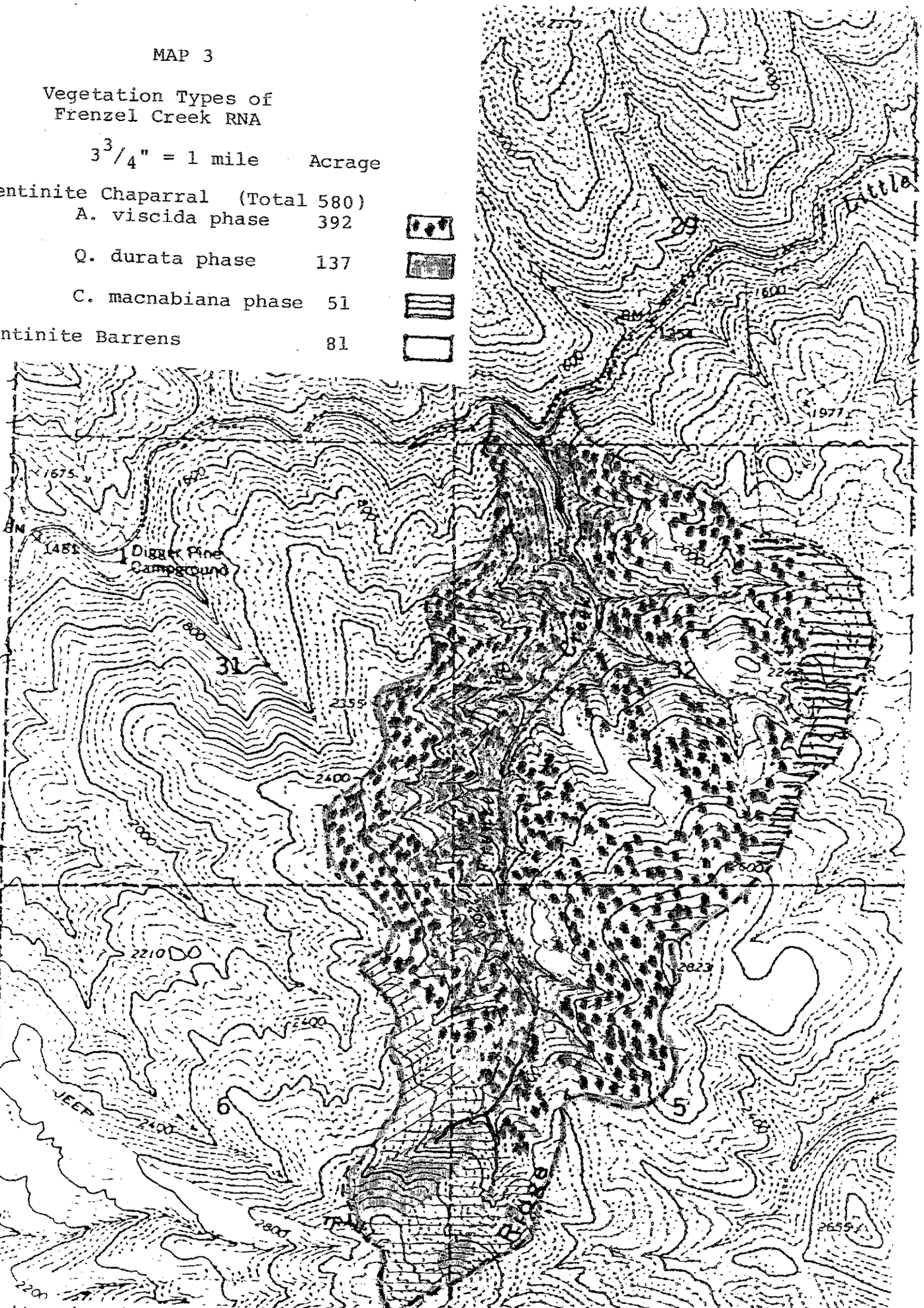
The strict serpentinite riparian zone is best developed all along the lower two-thirds of Frenzel Cr. and along the small portion of

MAP 3

Vegetation Types of
Frenzel Creek RNA

$3\frac{3}{4}$" = 1 mile

	Acrage
erpentinite Chaparral (Total 580)	
A. viscida phase	392
Q. durata phase	137
C. macnabiana phase	51
erpentinite Barrens	81



ntinite Riparian	
strict riparian	11
Valley bottom	46
erpentinite riparian	3
erpentinite chaparral	
Mesic phase	39
xeric phase	27
oak Woodland	36
Total	827

Little Stony Cr. within the RNA boundaries. It also ranges up the three semipermanent tributaries of Frenzel Cr. in the central portion of Sect. 32 (see vegetation map) and for a short distance up the tributary on the west side of Frenzel Cr. in the NW ¼ of Sect. 5. The most characteristic shrubs of this zone in order of abundance are: Rhododendron occidentale, Salix breweri, and Calycanthus occidentalis. Other shrub and tree species found in this zone include Cupressus sargentii, Rhamnus californica ssp. crassifolia and along Little Stony Cr.; Alnus rhombifolia, Fraxinus latifolia, Cornus glabrata, Populus fremontii, and Acer macrophyllum.

The herbaceous understory vegetation in the strict riparian zone is highly characteristic. Most species are not found elsewhere in the drainage. It includes: Aquilegia eximia, Achillea millefolium, Lilium pardalinum, Stachys pycnantha, Epipactis gigantea, Castilleja miniata ssp?, Carex serratodens, Scirpus americanus, Senecio clevelandii, Eleocharis sp. Helenium bigelovii, Angelica tomentosa, and Juncus mexicanus. Additional species along Little Stony Cr. include: Equisetum laevigatum, E. arvense, Artemesia douglasii, Apocynum cannabinum var. pubescens, and Carex nudata. The dispersion of most of these herbaceous species along Frenzel Cr. is surprisingly uniform. All of them can usually be found in any given 10m creekside section.

The mesophytic serpentinite valley bottom association is dominated by Cupressus sargentii (fig. 5) and Umbellularia californica. These two trees are often mutually exclusive. Where both occur in the same area C. sargentii usually occupies the most favorable sites just back from the creeksides or in the more sheltered hollows on the north- or east-facing slopes. Umbellularia, on the other hand, is more confined to open north facing slopes or a region further back than sargentii from the creek. Usually only where sargentii is absent, such as along the upper one-third of

Frenzel Cr., do the shrubby trees of Umbellularia descend to the creek (Fig. 6 where they co-occur with four other wide-ranging shrubby sub-dominants of this association: Ceanothus integerrimus var. californicus, Rhamnus californicus ssp. crassifolius, Rhus diversiloba, and Cercis occidentalis. Other plants of the serpentinite chaparral commonly occur in this zone as do certain plants typical of the strict riparian zone (especially Rhododendron) indicating its transitional nature. Few, if any herbs and vines are restricted to this zone. However, some such as Calystegia occidentalis, Delphinium nudicaule, Dentaria sp., Pityrogramma triangularis, Bromus marginatus, and Melica californica are definitely centered in this association.

Five 10X10m plots were sampled in the Cupressus sargentii- dominated portion of this association. All five plots were sampled along Frenzel Cr., either traversing the stream or bordering upon it (see Tables 1-3). The first three of the plots represent uneven-aged Sargent stands that were not obviously damaged by fire in the past 50 to 100 years. These plots tended to have one or two relatively large cypresses over 25cm dbh, with several intermediate individuals between 8&16cm dbh, and a majority of small trees between 1&8cm. Between one and three seedlings (under 2m) occurred on each plot.

Plot four was on a burned area of creekside that was re-colonized by a thick growth of small cypresses ca. 20-30 years old and between 3&5 cm dbh. No trees over 5cm dbh occurred on the plot, but there were six seedlings (one only two years old). Plot five was an old growth stand of cypress dominated by three large trees between 47 and 63cm dbh. Only three other cypresses occurred on the plot and these ranged from 2 to 6 cm dbh. The largest Sargent on Plot 5 was ca. 65ft. (20m) tall.

The only other trees in these five plots were one individual each of Pinus ponderosa and P. attenuata. The shrub cover varied from plot

Figure 4. Boundary between serpentinite (left) and friction carpet rocks (right and foreground). Note contrasts between open Arctostaphylos viscida (left) and dense Adenostoma and Ceanothus cuneatus (right) chaparrals.

Figure 5. Typical valley bottom grove of Sargent Cypress along upper Frenzel Cr. Trees in foreground are 50-60 ft. tall.

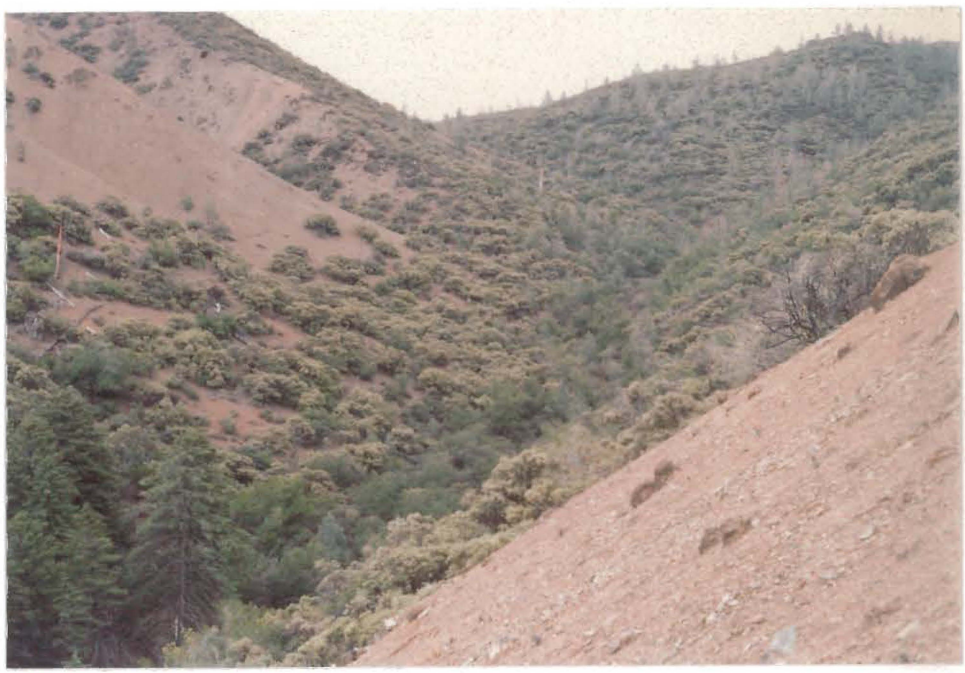


Figure 6. Upper limit of Sargent cypress (left) on Frenzel Cr., Umbellularia dominates along stream to right.

Table 1: Tree density in 10X10m plots in Cupressus sargentii dominated mesophytic serpentinite valley association.

Plot#	C. sargentii	P. ponderosa	P. attenuata
1	31	1	-
2	11	-	-
3	17	-	-
4	62	-	-
5	6	-	1

Table 2: Seedling and sapling density and tree basal area of C. sargentii-dominated plots.

Plot #	Seedling Density	Basal Area (cm^2)
1	3	2105.6
2	2	1754.3
3	1	1059.4
4	6	647.2
5	1	7228.4

Table 3: Mean and range of tree dbh on C. sargentii-dominated plots.

Plot #	Mean dbh(cm)	Range
1	9.5	0.5-33.5
2	14.5	0.5-35.0
3	9.0	1.5-19.0
4	3.5	0.5- 5.0
5	31.0	2.0-63.0

to plot depending on the distance from the creek. On three plots Rhododendron predominated, indicating an affinity to the strict riparian zone, while on two Quercus durata and Ceanothus integerrimus were the most important shrubs indicating more xeric affinities. Herbs were again reflective of the fact that each plot at least fringed on the creek where the densest vegetation occurs. Thus the most common herbs were such species as Epipactis, Stachys, Lilium, and Castilleja, the most common strict riparian herbs. None of the north-facing Sargent stands away from the creek were sampled. Most of these are dominated by large cypresses and often the understory is sparse and shady with only spindly Quercus durata (with thin nearly planar shade-leaves) and a few herbs such as Pedicularis densiflora (fig.7).

The abrupt halt of the nearly continuous distribution of C. sargentii up Frenzel Cr. at the NW¼ of Sect. 5 (see map 2) is somewhat puzzling. Perhaps it has to do with Sargent's strict restriction to serpentinized soils. Serpentinite continues above this point for almost a kilometer before the Franciscan rocks are met with. However, much of this section's creek alluvium is comprised of Franciscan rock washed downstream. Perhaps Umbellularia, which grows thickly in the same zone above this point has a competitive edge over Sargent in lightly serpentinized areas.

The rivulet association is best developed along the upper reaches of the several ravines branching to the east from Frenzel Cr. The intermittant nature of the water flow in these areas precludes the dense establishment of herbs and shrubs from the previous associations. This makes for a typically sunny exposure. The rivulet borders are frequently gravelly to sandy serpentinite which is noticeably moist up at least through the end of May (1983). The most widespread inhabitant of this sub-type of riparian vegetation is Mimulus brachiatus, a bright pink and magenta annual monkeyflower (see fig.1), which grows in thick

colonies of up to hundreds of individuals. Other species restricted to this zone include Centaurium sp. Mimulus bicolor, and M. glabrescens. Several other species found in adjacent chaparral also occur here including Epilobium minutum and Gayophytum sp. Occasional shrubs of Arctostaphylos viscida, Quercus durata, Rhamnus californicus ssp. crassifolia, and others overhang the rivulets, as do large specimens of MacNab Cypress. The shade cast by these woody plants inhibits the growth of the annual herbs making the distribution of this association somewhat patchy and irregular.

Serpentinite Chaparral:

This is the dominant vegetation type in the Frenzel drainage. In one form or another serpentinite chaparral covers ca. 70% of the RNA. Included within this type are two subtypes and several phases which vary in their dominant components depending upon slope exposure and perhaps frequency of fire.

The "mixed" subtype of serpentinite chaparral is the most extensive and is dominated by two species of shrubs, Arctostaphylos viscida and Quercus durata, with a lesser mixture of four other shrubs, Ceanothus jepsonii var. albiflorus, Garrya congdoni, Heteromeles arbutifolia, and (in more disturbed sites) Eriodictyon californicum. The A. viscida phase dominates the more xeric exposures including most main ridgetops, spur ridges, and west-facing slopes; while the Quercus durata phase predominates on more sheltered east, northeast, and northwest exposures. The size of old indivuduals of A. viscida may be very large. In many places shrubs 4m high and with bases of 35-50cm diameter are common. There are extensive areas of dense old growth manzanita on the west side of the upper drainage where the branches of adjacent plants intermingle and form nearly impenetrable stands. In the Q. durata phase the typical height of shrubs is much lower, from 0.75 to 1.5m, and

small, rocky openings between individual oak shrubs or larger (clonal ?) patches are common.(Fig. 8).

In most mixed stands shrub density is relatively high for serpentinite chaparral, although rarely as high as in the non-serpentinite chaparral in the upper drainage.

Pinus sabiniana is the only tree consistantly found in the mixed subtype. It varies widely in its density and stature. Throughout most of the serpentinite chaparral it is scattered with less than one tree per $100m^2$. Occasionally it forms woodlands with up to three large trees per $100m^2$. In such areas Digger Pine is dominant over the shrubs, but because the area of dominance is very local I have not formally included a P. sabiniana woodland vegetation type. Understory shrubs in such areas do not differ in density and composition from adjacent chaparral stands. There are large areas on both the east and west slopes where no P. sabiniana occurs.

Herbs of all phases and subtypes of serpentinite chaparral occur primarily in the rocky openings between the shrubs or at the edges of the canopy shadow cast by them. Species characteristic of the more shady exposures include: Chlorogalum pomeridianum, Lomatium ssp. Pedicularis, densiflora, Zigadenus fremontii, Calochortus amabilis, Montia perfoliata, Silene campanulata ssp. glandulosa, Athysanus pusillus, Claytonia gypsophylloides, Melica torreyana, Onychium densum, Thysanocarpus curvipes, Fritillaria recurva, Brodiaea pulchella, and Senecio greenei. Species characteristic of sunny exposures include: Allium falcifolium, Gilia capitata, Clarkia concinna, Galium andrewsii, Eriophyllum lanatum, Chaenactis glabriscula var. gracilenta, Malacothrix floccifera, Epilobium minutum, Cryptantha intermedia, Asclepias cordifolia, Streptanthus breweri, Calystegia subacaulis, Arenaria douglasii, Nemacladus montanus, Erysimum capitatum, Castilleja roseana, Eriogonum nudum, Bromus rubens, B. mollis, and Festuca dertonensis.

The other subtype of serpentinite chaparral is dominated by MacNab Cypress and occurs only along the dry, exposed ridgetop area on the northeast side of the RNA. I include the MacNab stands in chaparral because the Loveladý Ridge population is primarily of a shrubby habit (plants usually with several branches from near the base) and shares many shrubs and herbs with adjacent mixed chaparral. Locally C. macnabiana may be subdominant in the A. viscida phase of mixed chaparral. However in ca. 70% of the area covered by MacNab in the drainage, it(MacNab) is the dominant plant (fig. 9).

Two phases occur in the Frenzel drainage. Both are strongly dominated by the cypress, but differ in the stature of the mature MacNabs and in the composition of the subdominant vegetation.

The first phase is the most widespread in the drainage and occurs on the rounded ridgetops and south-and west-facing slopes. This "exposed" phase is composed of shrubby trees of MacNab and a lesser mixture of A. viscida, Q. durata, Adenostoma fasciculata, and Ceanothus jepsonii. This is the only phase of serpentinite chaparral where Adenostoma attains any importance. It is otherwise more or less restricted to non-serpentinite in the drainage. The exposed phase is also characterized by its rather uniform height. Mature stands are rarely taller than 4m and the cypress are usually only marginally taller than mature A. viscida. Thus, from a distance this phase appears much like typical mixed serpentinite chaparral. Densities of the MacNab shrubs are often higher than typical "mixed" chaparral shrub densities, particularly in more recently burned areas. In sites undisturbed by fire for 50-100 years MacNabs begin to thin out and dead and unhealthy cypresses are fairly common, presumably having suffered from overcrowding. In general west-facing exposures are denser than south-facing or ridgetop sites. Herbs of this phase are similar to those of the sunnier mixed serpentinite chaparral.

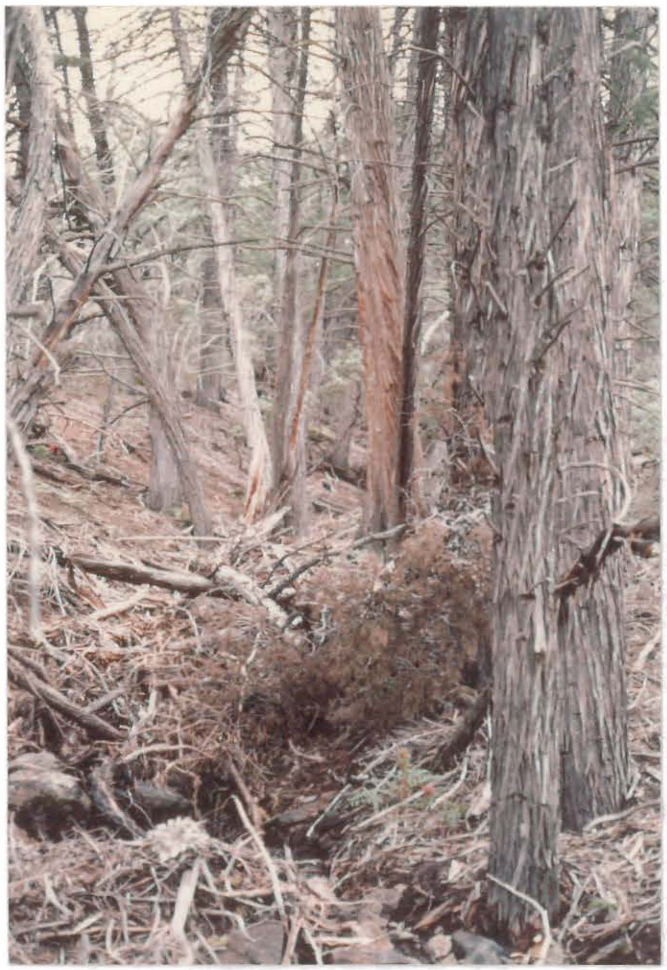


Figure 7. Sparse understory of dense north-facing Sargent Cypress grove.

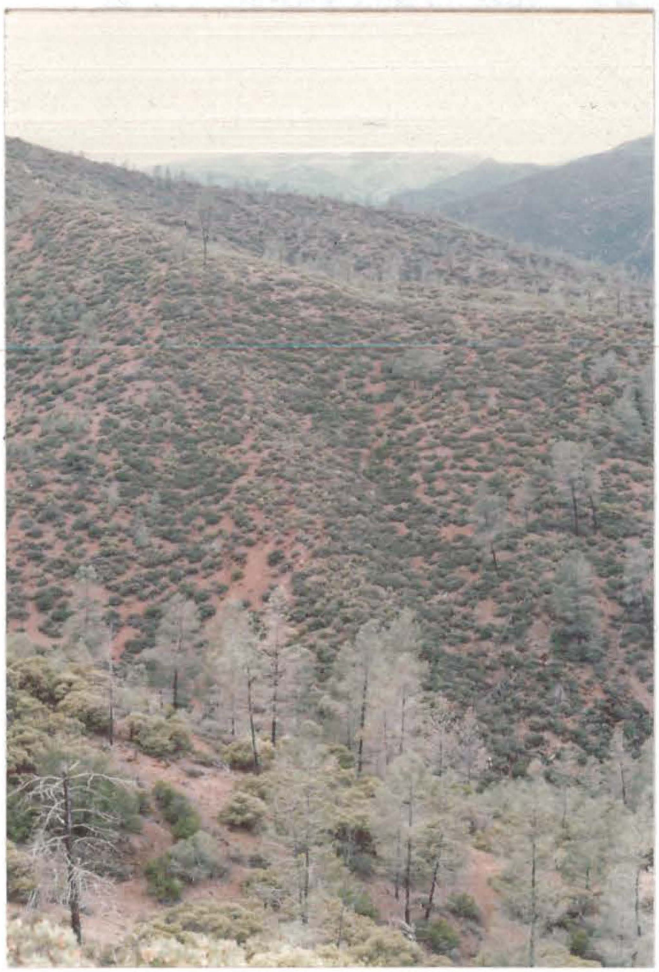


Figure 8. Looking west across Frenzel Cr. Canyon, Quercus durata (dark green) predominating on far east-facing slope, A. viscida (pale green) on west-facing slope in foreground.

Figure 9. 30-year-old MacNab cypress dominating on the 1950 Frenzel Burn. Insect net is 46 in. high.

However, a few species such as Lasthenia chrysostoma, Lotus subpinnatus, and Malacothrix floccifera were more common than away from the MacNab stands.

Four 10X10m plots were sampled in this phase and are represented by plots 1 through 4 in tables 4 and 5. In the first three plots most cypress were between 3 and 4m in height. Older trees had dome-shaped crowns which often spread widely enough to form a continuous canopy. Duff under the trees was thicker than in any other serpentinite chaparral phase with ca. 1½ inches of old scales and branches in some areas. Plot#1 faced due south and was dominated by middle-aged cypress ca. 50-60 years old. The Adenostoma and A. viscida tallied were peripheral to the main stand sampled and much smaller in stature. Plot #2 faced south and consisted of more widely spaced mature trees, perhaps 80-120 years old. These individuals were between 4 and 4.5m tall and between 10 and 30 cm in basal diameter. Adenostoma was again the most common associate and again was largely peripheral and volumetrically much less important than MacNab. Plot #3 faced west and was on a steeper, rockier slope than #1&2 and contained a wider range of age classes of MacNab from 5 to 27cm basal diameter. A. viscida attained more importance than previous plots with one old shrub ca. 4m tall (as tall as most MacNabs on this plot). Adenostoma was a much less important shrub on this plot.

In 1950 a large area of the east-central Frenzel drainage was burned, some of which was covered by middle-aged to old-growth MacNab. Seedlings of MacNab, A. viscida, Pinus sabiniana, and C. jepsonii sprang up abundantly over much of the burn. Stump sprouts of Q. durata are vigorous in the area as well. Plot #4 was sampled in this area. MacNab saplings ranged from ca. 0.5 to 1.5 m tall and several aged were between 18 and 31 years old. Nowhere were any MacNab seedlings found under 15

Table 4. Tree and shrub density on MacNab serpentinite chaparral 10X10m plots.

Plot #	MacNab	Heterom.	C.cun.	Adenost.	A.visc.	Q.dur.	P.sab.	C.jeps.	C.bet.
1	30			21	8				
2	14			15	1	1			
3	27			2	6	3		1	
4	38				17	29	2	10	
5	13				5	7	1		2
6	8	4	2			6	1		3

Table 5. Basal area (measured from the ground) and mean and range of basal diameters for MacNab Cypress on six 10X10m plots.

Plot #	Basal Area cm^2	Basal Diameter (cm) Mean	Range
1	1760.5	9.5	5.8-12.1
2	2754.7	15.4	10-30
3	1993.4	12.3	5-27
4	268.6	2.6	0.5-4.0
5	2524.1	17.7	9.5-26.0
6	8636.8	34.5	5.5-65.0

years old on this burn. It seems clear from the even age of most of the sampled plots and the paucity of young seedlings, that all significant MacNab regeneration in the drainage is closely tied to fire.

The second phase of MacNab chaparral is restricted to sheltered north slopes and ravine heads. It is characterized by taller, more massive C. macnabiana that are more consistantly tree-like in general habit. The age of some of these specimens must be over 200 years, and the mesic, sheltered coves they occur in suggest that they have been spared from recent fires by their peculiar location. On these mesic sites there occur two shrubs, Cercocarpus betuloides and Ceanothus cuneatus which like Adenostoma are restricted to serpentinite soils in the MacNab zone at Frenzel Creek. The most important subdominants of this sheltered phase are Quercus durata, A. viscida, and Heteromeles arbutifolia. Herbs of this phase are similar to the more shady stands of mixed serpentinite chaparral, the most important species are probably Pedicularis densiflora, Senecio greenei, and Montia perfoliata.

Plots # 5 and 6 represent MacNab stands on these sheltered sites. Plot 5 was on a moderatly sloping north exposure with large old growth C. macnabiana, A. viscida, and Q. durata. It also contained a Digger Pine ca 8.5m tall. Average height of the MacNabs on this plot was ca. 5m. Plot #6 is representative of the largest and best developed stands of MacNab at Frenzel Cr. It was at the head of a ravine and contained mature to senescent trees from 5.5 to 7m tall. The trees had well developed trunks up to 65cm dbh. The understory vegetation was sparse except for Q. durata on the periphery and a few small Cercocarpus, C. cuneatus, and Heteromeles.

The Barrens:

The sparsest vegetation type in the RNA occurs on the highly

sheared matrix zones of serpentinite where the soil is made up of rather deep deposits (often five feet or more) of sandy to gravelly rock. No shrubs or trees regularly grow in these areas, although P. sabiniana and A. viscida may invade their outer edges as very widely dispursed individuals.

The herbaceous vegetation of the barrens varies little depending upon slope exposure and it is consistantly sparse. No annual grasses grow regularly in this zone and only a handful of species of forbs. The few species that do grow here are by-in-large restricted to this environment.

The most ubiquitous species are the jewelflower Streptanthus morrisonii (aff.), the wild buckwheats Eriogonum vimineum, E. nudum, and E. dasycarpum, the undetermined wild onion Allium sp?, and the milkweeds Asclepias cordifolia and A. solanoana. More restricted species include Streptanthus breweri and Eriogonum ursinum var. nervulosum (the latter restricted to north-facing slopes). Several other species of the serpentinite chaparral such as Epilobium minutum and Cryptantha intermedia also occur regularly.

Non-serpentinite Vegetation:

There are three distinctive vegetation types that occur on the non-serpentinite rocks at the head of the drainage. Two, the non-serpentinite chaparral and riparian associations, are analogs of the serpentinite forms of the same names. A third type, the pine-oak woodland, is a mesophytic vegetation allied to typically more mid-elevation and coastal associations.

Non-serpentine riparian:

A small section of upper Frenzel Creek is permanent or semi-permanent and is lined with trees, shrubs and herbs typical of

non-serpentinite riparian zones along smaller creeks in the North Coast Ranges. The following trees occur as scattered individuals along this stretch: Populus fremontii, Salix laevigata, and Sambucus mexicana. Umbellularia californica is the most common tree, growing in the same zone as it does above the distribution of Cupressus sargentii on serpentinite. The shrubs and vines; Vitis californica, Rubus ursinus, Rhus trilobata, and Clematis lingustifolia are common in this zone. Streamside herbs include; Potentilla glandulosa, Cystopteris fragilis, Adiantum jordanii, Perideridia kelloggii, Lotus sp. and Datisca glomerata. The majority of these herbaceous and woody plants do not occur on adjacent serpentinite.

Umbellularia's presence along the intermittant creek suggests that its similar position along Frenzel Cr., just above the Sargent groves, may have something to do with requiring less (or tolerating less) water than Sargent through the dry months. It also may have to do with Sargent's possible poor competitive powers on non-serpentinized substrates, as was previously mentioned.

Pine-oak woodland:

This vegetation type occurs on north-, northeast-, and northwest-facing slopes at the head of the drainage. These slopes are usually steep, between 30 & 65^{o}, and often carry a nearly continuous canopy of low 20-30ft. trees of Canyon Oak (Quercus chrysolepis). Emerging from this canopy is an irregular layer of 30-50ft. Knobcone Pine (Pinus attenuata) and occasional P. sabiniana up to 70 ft. The understory is usually sparse, but frequently has large isolated shrubs of Cercocarpus betuloides, Heteromeles arbutifolia, Arctostaphylos manzanita, and A. canescens reaching sometimes up to the oak canopy. The small stature of the oaks, the presence of these old chaparral shrubs, and the even-aged stand of Pinus attenuata suggests that much of this area burned

ca. 50 years ago. On one ca. 5-acre northwest slope of Lovelady Ridge, larger and presumably much older pines and oaks must have been spared from the fire (fig. 10).

Many of the smaller shrubs and herbs are a mixture of montane and coastal species and include: Berberis dictyota, Lotus crassifolius, Cynoglossum grande, Symphoricarpos acutus, Ribes californicum, Dodecatheon hendersonii, Sanicula crassicaulis, and Keckiella lemmonii. Rhus diversiloba is the most common understory species.

Non-serpentinite chaparral:

Grading into the pine-oak woodland on northeast-facing slopes is a phase of chaparral dominated by tall shrubs of Cercocarpus betuloides, Ceanothus cuneatus, Quercus wislizenii var. frutescens, and Heteromeles. Adenostoma fasciculatum, Pickerengia montana, Quercus durata, Arctostaphylos canescens, A. glandulosa, Lonicera interupta, Clematis lasiantha, Ceanothus integerrimus, and Rhus diversiloba also occur to a lesser degree in this mesic phase of chaparral. The herbaceous cover in this zone may be very dense (especially in the valley bottom) and includes: Dodecatheon hendersonii, Stellaria nitens, Lithophragma heterophylla, Daucus pusillus, Montia perfoliata, Nemophylla pedunculata, Ranunculus hebecarpus, Marah watsonii, Scutellaria tuberosa, Sanicula crassicaulis, Mimulus gutattus, Amsinkia intermedia, Lotus subpinnatus, Erodium cicutarium, Cerastrum viscosum, Camissonia contorta var. epilobioides, and Brodiaea pulchella. The grasses; Bromus rubens, B. mollis, and Melica californica, are also common. The shrub cover varies from very dense on steep slopes to more open with small grassy patches near valley bottoms and on flats.

On more open ridgetops, particularly on the west side of the drainage, a second more xeric phase of chaparral occurs. This phase is dominated by a thick, almost impenetrable growth of Adenostoma and Ceanothus cuneatus (fig. 11) with lesser numbers of Arctostaphylos manzanita,

Figure 10. Looking east across head of Frenzel Cr. drainage, pine-oak woodland on upper right, mesic non-serpentinite chaparral in foreground.

Figure 11. A view northeast from the head of Frenzel Cr. overlooking xeric Adenostoma-Ceanothus cuneatus chaparral with Pinus attenuata, April 1983.

A. glandulosa, A. canescens, Quercus wislizenii var. frutescens, Q. durata, Q. X morehus, Heteromeles, Cercocarpus, and a few shrubs of Ribes malvacium and Haplopappus linearifolius.

Herbs in this zone are relatively few because of the thick shrub cover, but annual Bromus and other grasses are common in the few natural openings. On the ridgetop fuelbreaks herbs such as Erodium cicutarium, Senecio vulgaris, Agoseris heterophylla, and Orthocarpus attenuatus are common.

VI. SOME AREAS OF POTENTIAL RESEARCH AT FRENZEL CREEK

The Frenzel Creek RNA was established as an area for study of the unique Californian serpentinite flora. In the past 12½ years since its establishment research in this area has been negligable. With the large number of serpentinite-adapted taxa, the presence of the cogeneric cypresses, and an area of non-serpentine in the same drainage, there are many possible directions for research.

The presence of the two species of cypress in the drainage provides biologists with several interesting subjects for research, some of which have already been mentioned. Closer inspection of both species for signs of hybridization, the possible differences in effective regeneration between the two species, the cause of the abrupt limit of Sargent Cypress along upper Frenzel Cr., and the possible historical differences between Coast Range and Sierra MacNab might all be determined with more detailed study at Frenzel Creek and other comparative stands. The answers to these and related questions could elucidate the evolutionary paths followed by both species and unravel the reasons for their current edaphic and geographic restrictions.

Another profitable topic which has already received some attention (e.g., Kruckeberg 1954) is the ecotypic differentiation of serpentinite

and non-serpentinite species. Certain species at Frenzel Creek such as Gilia capitata are already known to have different edaphic ecotypes. However, many other herbs , shrubs, and a few trees occur on and off serpentinite in the drainage or adjacent areas. It would be instructive to compare such species as Clarkia concinna, Brodiaea pulchella, Lilium pardalinum, Gallium nuttallii, Delphinium nudicaule, Lotus subpinnatus, and some of the non-native annual Bromus and Festuca species. Among the shrubs and trees, such species as Cercocarpus betuloides, Heteromeles arbutifolia, Adenostoma fasciculatum, Quercus durata, Pinus sabiniana, Ceanothus integerrimus, and Rhus diversiloba occur on and off of serpentinite in the RNA. It is likely that there are different pathways of differentiation between ecotypes based upon the evolutionary constraints of each taxa.

Another field of investigation possible at Frenzel Creek involves the larger taxa which are poorly represented on serpentinite. Certain families such as the Ranunculaceae, Ericaceae, Rosaceae, Fabaceae, and large genera such as Penstemon are typically absent from serpentinite. Yet, several species in these families including Rhododendron occidentale, Arctostaphylos viscida, Delphinium nudicaule, Aquilegia eximia, Clematis lingustifolia, Heteromeles, Cercocarpus, Adenostoma, Lotus subpinnatus, Cercis occidentalis, and Lupinus albifrons are not rare on serpentinite at Frenzel Creek. The causes for the broad-scale intolerance of serpentinite by these groups are varied and many are unclear. By investigating the few serpentinite-tolerant species within these groups the reasons for their general absence from this substrate may be elucidated.

Only one species of manzanita, A. viscida, occurs widely on serpentinite at Frenzel Creek. Yet, three species are common in the upper drainage. According to Gottlieb (1968) the most common non-serpentinite species, A. canescens, hybridizes readily with A. viscida

in the Siskiyou Mountains. Several putative hybrids between these species were seen in the upper drainage. All of them were found off of serpentinite, indicating perhaps that the necessary genes from A. viscida confering serpentinite tolerance were not part of the hybrid plants. With further study of back-crosses of these two species it may be possible to find the degree of relatedness to pure A. viscida necessary for survival on serpentinite.

Raven and Axelrod (1978) suggest that one of the most instructive studies to clarify the history and evolution of a serpentinite-adapted group of plants would be on the genus Hesperolinon. This genus is represented by two species in the drainage and three or four other species occur within several miles of the RNA. All species in the genus are apparently restricted to serpentinite and much could be learned about the requirements of time, isolation, and other factors necessary for speciation on serpentinite by studying the genus.

Additional study should be devoted to the newly discovered subspecies of Castilleja miniata and to the Allium if it is indeed a new taxon. By comparing chromosome numbers of other species of Castilleja in the area it may be possible to find the other parent of this new taxon One likely candidate is the annual serpentinite endemic C. spiralis, which occurs just east of the RNA along roadside seeps(with C. miniata ssp. nov.).

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APPENDIX I

Vascular Plants of Frenzel Creek RNA

This list includes all species identified by me in April, May, and June 1983 and a few species not seen by me, but reported for the RNA by Isle et al. (1978). The following symbols represent vegetation types:

sb ----------serpentinite barrens
sr----------serpentinite riparian zone
svb----------serpentinite valley bottom association
sc----------serpentinite chaparral (includes all phases)
nsr----------non-serpentinite riparian zone
nsc----------non-serpentinite chaparral (both phases)
pow----------pine-oak woodland

About 180 taxa are included. Taxonomy is generally from Munz (1968).

Amaryllidaceae:
Allium amplectens sr
A. falcifolium sc
A. sp? sb
Brodiaea (Tritelia) pedunculata sr
B. pulchella

Anacardiaceae:
Rhus diversiloba pow, sc, nsc, sr, nsr, svb
R. trilobata nsr, sr (L. Stony Cr.)

Apocynaceae:
Apocynum cannabinum var. pubescens sr (L. Stony Cr.)

Asclepiadaceae:
Asclepias cordifolia sb, sc
A. solanoana sb, sc

Berberidaceae:
Berberis dictyota pow

Betulaceae:
Alnus rhombifolia sr (L.Stony Cr.)

Boraginaceae:
Amsinkia intermedia nsc
Cryptantha intermedia sc, sb
Cynoglossum grande pow, nsc

Calycanthaceae:
Calycanthus occidentalis sr

Campanulaceae:
Nemacladus montanus sc

Caprifoliaceae:
Lonicera interupta svb, sc, nsc, pow
Sambucus mexicana nsr

Symphoricarpos acutus pow

Caryophyllaceae:
Arenaria douglasii sc
Cerastium viscosum nsc
Silene campanulata ssp. glandulosa sc, svb
Stellaria nitens svb, nsc

Compositae:
Achillea millefolium sr
Agoseris heterophylla nsc, sc
Artemisia douglasii sr (L.Stony Cr.)
Baccharis viminea sr (L.Stony Cr.)
Calycadenia pauciflora sc
Chaenactis glabriscula var. gracilenta sc
Eriophyllum lanatum sc
Haplopappus linearifolius nsc
Hieracium albiflorum svb
H. greenei svb
Helenium bigelovei sr
Malacothrix floccifera sc
Microseris linearifolia sc
Lasthenia chrysostoma ssp. gracilis sc
Senecio clevelandii sr
S. greenei sc, svb
S. vulgaris
Solidago canadensis ssp. elongata sr

Cornaceae:
Cornus glabrata sr (L. Stony Cr.)

Convulvulaceae:
Calystegia subacaulis sc svb
C. occidentalis sr, svb

Cruciferae:
Athaysanus pusillus svb
Dentaria pachystigma var. dissectifolia (?) svb
Erysimum capitatum svb, sc
Streptanthus breweri sb, sc
S. b. var. hesperidus sc
S. morrisonii sb
Thysanocarpus curvipes svb, sc

Cucurbitaceae:
Marah watsonii nsc, pow

Cupressaceae:
Calocedrus decurrens svb (L. Stony Cr.)
Cupressus macnabiana sc
C. sargentii sr, svb

Cyperaceae:
Carex nudata sr (L. Stony Cr.)
C. serratodens sr
Eleocharis montividensis sr
Scirpus americanus sr

Datiscaceae:
Datisca glomerata nsr

Equisetaceae:
Equisetum arvense sr (L. Stony Cr.)
E. laevigatum sr (L. Stony Cr.)

Ericaceae:
Arctostaphylos canescens var. candidissima nsc,pow
A. canescens var. sonomensis (?) nsc
A. glandulosa nsc, pow
A. manzanita nsc, pow
A. viscida sc
Rhododendron occidentale sr, svb

Fagaceae:
Quercus chrysolepis pow
Q. durata sc, nsc
Q. X morehus nsc
Q. wislizenii var. frutescens nsc, pow

Garryaceae:
Garrya congdoni sc, nsc

Gentianaceae:
Centaurium sp. sr

Graminae:
Bromus madritensis sc
B. marginatus svb
B. mollis sc, nsc
B. pseudolaevipes sc
B. rubens sc, nsc
B. tectorum sc, nsc
Elymus glaucus sc
E. triticoides sr (L. Stony Cr.)
Festuca dertonensis sc
F. reflexa sc, nsc
Melica californica svb, nsc
M. torreyana sc, svb
Sitanion hanseni sc
S. hystrix sc
Stipa cernua (Isle et al)

Hydrophyllaceae:
Eriodictyon californicum sc nsc
Nemophila pedunculata pow, nsc
Phacelia egina sc
P. heterophylla sc

Iridaceae:
Iris douglasiana svb, sc

Juncaceae:
Juncus mexicanus sr

Labiatae:
Monardella villosa ssp. sheltonii svb (L. Stony Cr.)
Stachys pycnantha sr
Scutellaria antirrhinoides sr (L. Stony Cr.)
S. tuberosa nsc
S. californica sr (L. Stony Cr.)

Lauraceae:
Umbellularia californica svb, sr, nsr

Leguminosae:
Astragalus clevelandii sr (L. Stony Cr.)
Cercis occidentalis sr, svb, nsc
Lotus crassifolius pow
L. hermannii (?) nsr
L. subpinnatus sc nsc
Lupinus albifrons sr (L. Stony Cr.)
Pickerengia montana nsc

Liliaceae:
Calochortus amabilis sc, svb
Chlorogalum pomeridianum var. minus (?) sc
Fritillaria recurva sc svb
Lilium pardalinum sr
Zigadenus fremontii sc nsc
Z. fontanus sr

Loasaceae:
Mentzelia laevicaulis sc

Loranthaceae:
Phoradendron bolleanum sc (on C. macnabiana)
P. flavescens var. villosum pow (on Q. chrysolepis)

Linaceae:
Hesperolinon drymarioides (Isle et al. 1978)
H. californicum (L. Stony Cr.) sc

Oleaceae:
Fraxinus dipetala svb (L. Stony Cr.)
F. latifolia sr (L. Stony Cr.)

Onagraceae:
Camissonia contorta var. epilobioides nsc
Clarkia concinna sc svb
C. gracilis ssp. albicaulis (Isle et al.)
Epilobium minutum sc sb svb

Orchidaceae:
Epipactis gigantea sr
Habenaria sp. (Isle et al.)

Orobanchaceae:
Orobanche fasciculata var. franciscana sc (L. Stony Cr.)

Pinaceae:
Pinus attenuata pow, nsc
P. ponderosa sc, sr
P. sabiniana sc, nsc, pow

Polemoniaceae:
Gilia capitata sc nsc
Microsteris gracilis sc

Polygonaceae:
Eriogonum nudum var. oblangifolium sc sb

Eriogonum dasycarpum sb
E. ursinum var. nervulosum sb
E. vimineum sb, sc

Portulacaceae:
Montia (Claytonia) gypsophiloides sc svb
M. perfoliata sc, syb, nsc, pow
M. spathulata var. exigua sc

Pteridaceae:
Adiantum jordanii nsr, pow
Cystopteris fragilis nsr
Onychium densum sc, svb
Pellaea mucronata sc
Pityrogramma triangularis svb, pow

Rhamnaceae:
Ceanothus cuneatus sc nsc
C. integerrimus var. californicus svb, nsc
C. jepsonii var. albiflorus sc
Rhamnus californica ssp. crassifolia sr, svb

Rosaceae:
Adenostoma fascicualtum nsc, sc
Cercocarpus betuloides nsc, sc
Heteromeles arbutifolia pow, nsc, sc
Potentilla glandulosa nsr
Rosa californica sr (L. Stony Cr.)
Rubus ursinus nsr

Rubiaceae:
Galium andrewsii sc, svb
G. nuttallii sc nsc pow, svb
G. sp. sc
G. aparine nsc

Salicaceae:
Populus fremontii nsr, sr (L. Stony Cr.)
Salix breweri sr
Salix laevigata nsr

Saxifragaceae:
Lithophragma heterophylla pow, nsc
Ribes californicum pow
R. malvaceum nsc

Scrophulariaceae:
Castilleja miniata ssp. nov. sr
C. roseana (martini) sc
Collinsia greenei sc
Keckiella lemmonii pow
Mimulus bicolor sr
M. brachiatus sr
M. glaucescens sr
M. guttatus nsr
Antirrhinum subcordatum (Isle et al)
A. breweri sc
Orthocarpus attenuatus nsc

Pedicularis densiflora sc,svb, nsc
Verbascum blattaria nsc

Umbelliferae:
Angelica tomentosa sr
Daucus pusillus nsc
Lomatium macrocarpum sc
L. tomentosum sc
Perideridia kelloggii nsr
Sanicula crassicaulis pow, nsc

Vitaceae:
Vitis californica nsr, sr (L. Stony Cr.)

APPENDIX II

Vertebrates of Frenzel Creek RNA

FISH (likely species derived from Moyle 1976):
Rainbow Trout: in Frenzel and L.Stony Cr.
Riffle Sculpin; likely in both creeks
Speckled Dace; likely in L. Stony Cr.
Hardhead; common in L. Stony Creek in June
Hitch; a few in L. Stony Creek in June
California Roach; likely in L. Stony Cr.
Sacramento Squawfish; likely in L. Stony Cr.
Sacramento Sucker; likely in L. Stony Cr.

AMPHIBIANS (Likely species derived from Stebbins 1966):

Rough-skinned Newt; likely in Frenzel drainage
Ensatina; likely in Frenzel drainage
California Slender Salamander; likely in Frenzel drainage
Arboreal Salamander; possible in Frenzel drainage
Western Toad; L. Stony Cr. in April
Pacific Treefrog; L. Stony Cr. in April
Foothill Yellow-legged Frog; common along Frenzel Cr.

REPTILES (Likely species derived from Stebbins 1966):

Western Pond Turtle; fairly common in L. Stony Cr.
Western Fence Lizard; uncommon in Lower Frenzel drainage
Sagebrush Lizard; common throughout drainage
Western Skink; likely in Frenzel drainage
Western Whiptail; common near the top of Lovelady Ridge
Southern Alligator Lizard; likely in Frenzel drainage
Northern Alligator Lizard; likely in drainage
Rubber Boa; possible in upper Frenzel drainage
Ringneck Snake; possible in Frenzel drainage
Sharp-tailed Snake; possible in upper drainage
Striped Racer; possible in drainage
Racer; likely in drainage
Gopher Snake; likely in drainage
California Mountain Kingsnake; possible in drainage
Common Kingsnake; likely in drainage
Western Aquatic Garter Snake; common along L. Stony, Frenzel and tributarie
Western Terestrial Garter Snake; possible in drainage
Western Rattlesnake; likely in drainage

BIRDS (includes only those seen by me during April, May and June 1983):

Mallard; along L. Stony Cr. May
Wood Duck; along L. Stony Cr. April
Common Merganser; L. Stony Cr. April and May
Turkey Vulture; seen every visit
Red-tailed Hawk; Lovelady Ridge April, May
Golden Eagle; Upper Drainage, April

California Quail; heard in upper drainage in April
Mountain Quail; common in drainage every visit
Mourning Dove; seen every visit
Poor-will; flushed from chaparral in April
Annas Hummingbird; very common in April
Common (Red-shafted) Flicker; seen every visit
Hairy Woodpecker; heard in upper drainage in April
Ash-throated Flycatcher; Lovelady Ridge, May
Black Pheobe; common along L. Stony Cr. in April & May
Western Wood Pewee; L. stony Cr May & June
Barn Swallow; L. Stony Cr. April & May
Cliff Swallow; seen all visits
Violet-green Swallow; seen all three visits
Rough-winged Swallow; L. Stony Cr. April
Scrub Jay; common all three visits
Plain Titmouse; uncommon on Lovelady R. Macnab Cypress grove
Common Bushtit; common all visits
Wrentit; common all visits
Bewick's Wren; common all visits
Canyon Wren; lower drainage and L. Stony Cr. all visits
California Thrasher; singing throughout drainage in April
Blue-gray Gnatcatcher; MacNab Cypress grove April and May
Orange-Crowned Warbler; singing in April
Yellow-rumped (Audubons) Warbler; common transient in April
MacGillivray's Warbler; transient in upper drainage, April
Wilson's Warbler; L. Stony Cr. April
Brown-headed Cowbird; flying over Lovelady R. in May
Northern (Bullock's) Oriole; seen in cottonwood along L. Stony Cr., April
Western Tanager; in Sargent Cypress at mouth of Frenzel Cr. in April
Black-headed Grosbeak; in riparian vegetation April, May L. Stony Cr.
House Finch; flying over serpentinite chaparral April, May
Lesser Goldfinch; common all visits
Rufous-sided Towhee; common all visits
Brown Towhee; upper drainage, April
Sage Sparrow; upper drainage, April
Fox Sparrow; Lovelady Ridge April

MAMMALS (Likely species derived from Ingles 1965).

Sorex ornatus Ornate Shrew; possible
Scapanus latimanus Broad-handed Mole; serpentinite and nonserpentinite vegetation throughout.
Myotis californicus California Bat; roosts under serpentinite boulders on Lovelady Ridge, May
M. volans Hairy-winged Myotis; likely
M. evotis Long-eared Myotis; likely
M. yumanensis Yuma Bat; likely
Lasiurus cinereus Hoary Bat; likely
L. borealis Red Bat; likely
Eptesicus fuscus Big Brown Bat; likely
Pipistrellus hesperus Western Pipistrelle; likely
Antrozous pallidus Pallid Bat; likely
Plecotus townsendii Lump-nosed Bat; likely
Tadarida brasiliensis Brazilian Free-tailed Bat; likely
Lepus californicus Black-tailed Jackrabbit; scats seen on Lovelady Ridge
Sylvilagus bachmani Brush Rabbit; upper drainage in chaparral

Otospermophilus beecheyi Beechey Ground-squirrel; common along L.S. Cr.
Eutamias sonomae Sonoma Chipmunk; common in serpentinite and non-serp. chaparral
Sciurus griseus Western Gray Squirrel; fairly common in canyon bottoms
Thomomys bottae Botta Pocket Gopher; common throughout
Perognathus californicus California Pocket Mouse; likely
Peromyscus boylei Brush Mouse; likely
P. truei Pinyon Mouse; common in chaparral, 17% trapping success in April
P. maniculatus Deer Mouse; very common in valley bottom, 50% trap success in April
Neotoma fuscipes Dusky-footed Woodrat; possible
Urocyon cinereoargenteus Gray Fox; likely scats seen in April
Canis latrans Coyote; scats seen on all visits
Ursus americanus North American Black Bear; scats seem in April
Procyon lotor Raccoon; tracks along L. Stony Cr. in May
Bassariscus astutus Ringtail; likely
Mustella vison Mink; possible along L. Stony Cr.
Mustella frenata Long-tailed Weasel; likely
Mephitis mephitis Striped Skunk; tracks along L. Stony Cr. May
Spilogale putorius Spotted Skunk; likely
Felis concolor Mountain Lion; likely
Lynx rufus Bobcat; likely
Odocoileus hemionus columbianus Columbia Black-tailed Deer; common througho

ADDENDA

The undetermined Allium mentioned on p. 12 has been determined by Dale McNeal at the University of the Pacific as being an as yet undescribed variety of Allium catericola. Currently, a graduate student of his is working on the complex. The Frenzel Cr. plant differs from the species primarily by the leaf number, which is most often two.

Larry Heckard of the Jepson Herbarium (UCB) has found that the undescribed subspecies of Castilleja miniata (p. 12) has a chromosome count of N = 12. This is the typical base number for most Castilleja species and differs from the N = 24 of the nearest montane polyploid forms of C. miniata on Snow Mountain. C. spiralis, the annual moisture-loving species which co-occurs with the subspecies along Little Stony Cr. also has N = 12. That both forms can co-exist with the same chromosome counts is unusual and warrants special study. The new Frenzel Cr. C. miniata is clearly a very distinct subspecies.